UNITED STATES
CIVIL DEFENSE

Radiological Decontamination In Civil Defense

TM-11-6

FEDERAL CIVIL DEFENSE ADMINISTRATION

Radiological Decontamination in Civil Defense is one of a series of technical manuals prepared by the Federal Civil Defense Administration. These manuals provide detailed technical or specialized information in particular fields of civil defense.

If an enemy attack causes significant radiological contamination, it may be necessary to reduce the radiation hazard by decontamination processes. Certain vital areas such as communication centers and water pumping stations, and essential equipment such as fire-fighting apparatus and ambulances may require immediate decontamination so that they can be employed in civil defense activities. Later decontamination may be necessary in vital industrial plants and in places people must occupy for either civil defense or strategic military purposes. Even further decontamination may be required for general rehabilitation purposes.

Emergency decontamination procedures should not be started until authorities responsible for radiological defense have determined the extent of the hazard presented by the contamination and have decided that decontamination is necessary in the overall civil defense effort. The sequence of the later decontamination operations will be based on the relative importance of the contaminated areas or objects, and other considerations such as man-hours required, resources available, and alternative possible solutions.

Radiological Decontamination in Civil Defense provides information for all radiological defense personnel and serves as an operations manual for decontamination crews. The manual describes the various methods to be used by civil defense crews in decontamination operations. In most cases, the water method, using either cold or hot water with detergent added, or the steam method, will be the first decontamination operation used, as the materials are most readily available. One or more of the other methods described in this manual may then be used for further reducing radiation levels, depending on the use to be made of the area or material being decontaminated.

The procedures described in this manual require materials and equipment that for the most part are in common everyday use. Civil defense decontamination crews should include personnel who are familiar with the normal peacetime operation of such equipment.

This manual does not go into the matter of what constitutes safe levels or health hazards under emergency conditions. These matters are technical questions for the radiological defense personnel and the civil defense director to assess in terms of the overall situation at the moment. Information relating to the radiobiological reactions involved and the degree of immediate injury to be expected from varying dosages of radiation may be found in *The Effects of Atomic Weapons*.[1]

[1] *The Effects of Atomic Weapons*, U. S. Atomic Energy Commission, June 1950. For sale by the Superintendent of Documents, Washington 25, D. C.

UNITED STATES CIVIL DEFENSE

RADIOLOGICAL DECONTAMINATION IN CIVIL DEFENSE

FEDERAL CIVIL DEFENSE ADMINISTRATION
(Technical Manual)

UNITED STATES GOVERNMENT PRINTING OFFICE : MARCH 1952

For sale by the Superintendent of Documents, U. S. Government Printing Office
Washington 25, D. C. • Price 15 cents

ACKNOWLEDGMENT

The Federal Civil Defense Administration wishes to acknowledge its indebtedness to the Department of Defense for much of the source material used in the preparation of this manual. It is based primarily upon material furnished by the U. S. Naval Radiological Defense Laboratory in San Francisco, where a considerable amount of research and testing has been carried out to ascertain the value of various decontamination procedures on radioactive contaminated surfaces and equipment.

Acknowledgment is also made to the Atomic Energy Commission, the Public Health Service, the Veterans' Administration, and the Armed Forces Special Weapons Project for assistance in preparing this manual.

CONTENTS

Chapter	*Page*
1. Basic principles	1
Reducing the radiation hazard	1
Methods of decontamination	2
Gross decontamination	2
Protective measures	3
Equipment	3
Decontamination to the point of safety	3
Spread of contamination	4
2. Surface decontamination	5
Vacuum cleaning	6
Water hosing	6
Decontamination with steam	7
Use of detergents	8
Complexing agents	9
Organic solvents	11
Inorganic acids	12
Organic acids and mixtures	13
Decontamination with caustics	13
Abrasion methods	14
Flame cleaning	16
3. Aging and sealing	18
Necessary characteristics	18
Asphalt and asphalt concrete	18
Paints and plastics	19
Sealing with grout	19
4. Removal and storage	21
Demolition and concentration	21
Combustible material	21
Inert and fusible material	22
Precautions in handling	23
5. Storage methods	25
Burial on land	25
Entombment	26
Burial at sea	27
6. Conclusion	28

Appendix

Surface decontamination methods:

A. Classified by agent	29
B. Classified by type of surface	30

BASIC PRINCIPLES

1.1 In atomic warfare, radiological contamination occurs where radioactive substances (fission products and unfissioned bomb materials) are deposited, or where materials are made radioactive by the neutrons released during the explosion. The deposited contamination may be invisible and may be carried on dust or in water vapor depending on the type of detonation—water, ground, or air—and on weather conditions. The radioactivity produced by neutrons will probably be confined to the immediate area of the detonation, and might be in liquids, large solids, or dusts.

1.2 Civil defense decontamination operations will be undertaken only when the contamination constitutes a health hazard. This contamination consists of alpha, beta, and gamma radiations. The alpha rays come from unfissioned particles of the bomb (uranium or plutonium) which have a very long half-life or decay period. Alpha rays are poorly penetrating and, therefore, constitute an internal hazard only; i. e., they must get into the body to do harm. The beta and gamma rays come from the fission products or the material made radioactive by the neutrons. In general, the fission products and this material have a relatively short half-life. Beta and gamma rays constitute both internal and external hazards but, from a civil defense operations standpoint, are more important (especially the gamma rays) as external hazards.

1.3 The amount of contamination will depend on the type of bomb burst. A high air burst which causes the maximum destruction will result in no significant radiological contamination. The closer to the ground the burst, the greater the contamination hazard. A burst on or under the surface of the earth or under water could throw dangerous amounts of radioactive material over a wide area.

1.4 Although some areas may require more intensive decontamination than others, the methods will be the same for all degrees of contamination.

Reducing the Radiation Hazard

1.5 Radiation cannot be destroyed. However, methods have been devised to reduce or eliminate the lingering radiation hazard. These methods are used to effect radiological decontamination.

1.6 Lingering radiation is only a secondary threat in atomic warfare and should be viewed in that perspective. While it is true that in high intensities, radiation could force workers to leave their jobs, prevent persons from entering their homes, disrupt civilian and industrial operations, cause serious illness or even kill, the danger from radiation is not as great as from other aspects of atomic warfare such as blast and fire.

1.7 Everyone is constantly exposed to small amounts of radiation from natural sources and it is only in large amounts that it is dangerous. Research and experience have provided data as to the degree of danger to be expected and instruments have been developed to detect and measure radiation. This knowledge and these instruments will be used by civil defense workers in the process of decontamination, and in determining how much the hazard has been reduced.

Methods of Decontamination

1.8 Radiological decontamination is the reduction or removal of the health hazard resulting from contaminated materials. This is accomplished in three ways:

(*a*) *Surface decontamination.*—This consists of treating the surface so as to remove the contaminating agent, or reducing it to a safe level.

(*b*) *Aging and sealing.*—Aging consists of letting the radioactive material stand for a while to allow for a reduction of the concentration of radiation through natural decay, and sealing is the process of covering the substance with a sealing material.

(*c*) *Removal and storage.*—This consists of removing radioactive material from where it might constitute a hazard to personnel and burying, on land or at sea, or entombing the material.

1.9 Later chapters in this manual will describe these methods in detail.

Gross Decontamination

1.10 Gross decontamination is the rapid, large-scale, partial removal of contamination. It calls for the removal of contaminated debris and, along with it, much of the loosely held radioactive material. All three of the basic decontamination methods are used in gross decontamination. Since considerable radiation hazard may remain when this step is taken, a minimum of personal contact and a maximum of precaution against spreading contamination are required. The purpose of gross decontamination is to permit the emergency use of the area or equipment, or to serve as a preparatory step in a more complete decontamination operation.

1.11 Civil defense decontamination crews will be primarily concerned with gross decontamination rather than the more complete process.

Protective Measures

1.12 Decontamination crews must be protected against radiation. All decontamination procedures must be carried out under the guidance of radiological defense personnel.

1.13 Special clothing, covering as much of the body as possible, and having a minimum number of openings through which radioactive materials might penetrate, should be worn. The clothing will not stop some radiation from penetrating the body, but it will keep radioactive substances away from the skin.

1.14 For work in contaminated areas, special clothing should consist of coveralls (preferably one-piece), canvas bootees, and cotton or canvas work gloves. In heavily contaminated wet areas, the operator should wear water-repellent clothing. It should consist of coveralls, rubber boots, and rubber gloves. Headgear is essential at all times.

1.15 Coverall sleeves should be tucked into gloves and coverall legs taped tightly over the tops of boots. For most operations a filter mask is needed and some types of decontamination jobs require goggles. For ease of operation, lightweight clothing should be worn when possible.

1.16 Each worker should be supplied with a small instrument such as a dosimeter or film badge to measure his total radiation exposure. Where radiation intensities are high, workers can be protected by rotation among jobs of varying degrees of radiation hazard.

Equipment

1.17 The types of equipment and skills required for radiological decontamination are not new. Ordinary equipment now available such as cranes, power shovels, carryall scrapers, bulldozers, patrol graders, tankdozers, street sweepers, water hoses, and pressure sprayers, combined with careful techniques and common sense application of existing methods, will do the job.

Decontamination to the Point of Safety

1.18 In determining at what point an area is considered safe radiologically, the fact that radiation hurts people, not objects, should be kept in mind. Accordingly, decontamination should be carried out to the point where radioactivity no longer constitutes a health hazard. Decontamination need not be complete.

1.19 With each decontamination crew there should be a monitor equipped with a survey meter for measuring radiation intensity. With this device he can check the effectiveness of the decontamination. Areas in constant use may require intensive decontamination while those not in use may not require decontamination at all. For example, a bridge needed for truck traffic need be only partially decontaminated because personnel going across would be exposed to radiation for only a few minutes. However, if it were necessary for engineers to work for hours on this bridge, decontamination would have to be much more extensive to make the bridge radiologically safe.

Spread of Contamination

1.20 Radiological contamination might not stay on the outside of buildings and areas. It might in the form of dust or vapor sift through openings; or ventilating systems could draw in the radioactive material and spread it throughout a structure. Careless movement through a contaminated area might also spread the radioactive material. Persons coming from a contaminated area could spread contamination to an uncontaminated area. Dust in the wake of moving vehicles might spread contamination by sifting through openings in structures, or by riding the wind into uncontaminated areas. Extreme care should be taken by civil defense decontamination crews to prevent the spread of radioactive materials.

SURFACE DECONTAMINATION

2.1 The first decontamination process used by civil defense crews in almost all instances will be surface decontamination. The method of surface decontamination will depend on the type of surface and whether the object is fixed or movable. The method selected should be one that will not destroy the utility of the object. Choosing the right surface decontamination method requires a thorough knowledge of the different types of surfaces, the various methods used, and good judgment.

2.2 During any cleansing operation the material should be continually checked for radioactivity. As long as dangerous contamination remains, depending on the use to be made of the object, the process must be repeated or crews must follow it with detailed cleansing. In any event, cleaning and removal methods must be carried out with whatever degree of thoroughness is required to reduce the radiation hazard to a safe level.

2.3 Radioactive materials can cause recontamination after their removal from a surface. Such materials should not be allowed to scatter. Wetting down dust is one method of preventing this. Radioactive wastes should be under safe guard from the point of original location to the point of final disposition.

2.4 Methods of surface decontamination include cleaning with the following:

(*a*) Vacuum equipment.
(*b*) Water.
(*c*) Steam.
(*d*) Detergents.
(*e*) Complexing agents.
(*f*) Organic solvents.
(*g*) Inorganic acids.
(*h*) Acid mixtures.
(*i*) Caustics.
(*j*) Abrasion.
(*k*) Flame equipment.

2.5 Vacuum cleaning, water, and steam remove only the loosely held contaminated materials. Detergents and complexing agents may succeed in removing the tightly bound contamination, but will not attack material embedded in the surface to an appreciable extent. Organic solvents, acids, caustics, flame cleaning, and abrasion remove the outer layers of the surface material along with the contamination. The above methods are described in detail in this chapter, and summarized in the appendix.

983651°—52——2

Vacuum Cleaning

2.6 Vacuum cleaning methods are the most desirable. Vacuuming removes radioactive dusts lying on surfaces. It does not require the use of liquids which would entail the risk of chemical combinations on the surface nor does it involve the risk of dust hazards caused by abrasion methods. Radiological decontamination by vacuum cleaning is suitable for the interiors of buildings or vehicles. It may be necessary, however, to decontaminate further by other methods.

2.7 *Equipment.*—Vacuum equipment with a water-vapor dust-trap is the most serviceable type at present. An auxiliary exhaust filter system is a necessity to prevent the escape of radioactive material. Operators should wear dust-filter masks and goggles.

2.8 *Technique.*—When crews are working on interiors the concentration of dust must be kept down. Ventilation is one way of doing this; however, surfaces and areas in the vicinity should be cleansed of radioactive dusts before the ventilating system is started. A second way is to run an exhaust hose out a window or door to disperse the dust in the open, providing it does not create a health hazard. An adequate filtration system would be required with this method. Following vacuuming, the surface should be wiped with a damp rag. A dry cloth should never be used on a dry surface.

2.9 *Limitations.*—Use will cause equipment to become contaminated. Whenever dangerous amounts of radioactive materials are discharged through the exhaust or monitoring shows the equipment to be a radiation hazard, the equipment must either be decontaminated or replaced.

Water Hosing

2.10 Hosing will be one of the first and most commonly used methods of decontamination. Water under high pressure played upon surfaces has an erosive action which wears away contamination.

2.11 *Equipment.*—Standard fire-fighting equipment can be used. Personnel should wear complete water-resistant outfits.

2.12 *Technique.*—Crews should work from highest to lowest points so that drainage will not recontaminate areas previously washed. Control of contaminated spray should be maintained by hosing from the upwind side of the contaminated object. The most satisfactory operating distance is 15 to 20 feet from the object. Good drainage should be provided since radioactive material if allowed to collect in pools may lead to recontamination. If possible, special drainage facilities should be prepared to allow the waste water to flow directly to the sewage system or to removal points (rivers, bays, settling basins). Otherwise drains used for this purpose may become contaminated.

2.13 *Vertical surfaces.*—On vertical surfaces the water should be directed to strike the surface at an angle of 30° to 45°. A smaller angle of attack causes undue contamination of areas beyond the surface; a large angle risks a back spray upon the crew. If wind blows the spray, a canvas windbreak upwind of operations may help. If possible, the crew should operate so that the vertical surface itself acts as a partial windbreak.

2.14 *Horizontal surfaces.*—If the crew must walk on the surface they are decontaminating, they should go from the clean to the contaminated area, hosing the contaminated area before them. On horizontal surfaces the hose stream should point downward to strike the surface 10 to 15 feet in front of the crew. This provides effective erosive action. If the stream is directed closer to the crew than 10 feet, there is danger of back spray. If the stream is directed upward or straight out, much of its erosive power is lost.

2.15 For most efficient operation it is advisable first to determine the best rate for decontaminating an area. This can be done by hosing several sample areas for different periods of time, then determining how much the cleaning has reduced the radiation level in each case.

2.16 If it is not possible to use this process, the following approximate rates may be used:

(*a*) Four square feet per minute for a 100-gallon-per-minute stream.

(*b*) Eight square feet per minute for a 250-gallon-per-minute stream.

2.17 *Limitations.*—Even prolonged hosing will reduce surface contamination only about 50 percent. Water can penetrate porous surfaces, tending to carry decontamination deeper into the material and act as a medium for chemical reaction, making removal of contamination in many cases more difficult. It does not mix with oil; oil acts as a barrier between contamination and water.

2.18 In some instances uncontaminated water may be at a premium and not available for large scale decontamination operations. Hosing may have to be followed by other techniques.

Decontamination with Steam

2.19 Steam cleaning produces about 90 percent reduction in surface radioactivity. It cleans in much the same way as water, but is more effective because its high temperature melts surface grease and aids in dissolving many substances. Adding a detergent improves the decontamination action.

2.20 *Equipment.*—Standard steam spray equipment which does not recirculate the steam can be used. High-pressure hot water jet cleaners are also very effective. Crews should have waterproof clothing and filter masks. When working in confined or enclosed spaces, adequate ventilation must be provided.

2.21 *Technique.*—Operators should work from top to bottom and from the upwind side of the object. The same precautions for drainage should be observed as with water. The best rate of decontamination may be determined by sample cleansing. Otherwise a rate of 4 square feet per minute for equipment delivering 150 to 200 gallons per hour may be used. The steam gun should be held about 2 feet from the surface. When using a high-pressure hot water jet cleaner the operator may stand 10 to 15 feet away. This gives the operator more protection from surface radiation and from contaminated back-spray. Following the steam treatment the crews should hose down the object and the working space with water to remove any contamination left by the steam spray. Personnel also should be hosed down before taking off contaminated clothing.

2.22 *Limitations.*—The processes using steam have disadvantages common to water methods, and in addition there is a hazard presented by contaminated spray.

Use of Detergents

2.23 Detergents (soap, soap powder, and soapless detergents sold commercially for household cleaning) may be used with water in decontaminating oily or greasy surfaces. They facilitate the mixing of water and oil so that the oil remains in a stable suspension in the water in the form of minute droplets. The greasy film on the surface which would ordinarily repel water is broken up and carried away as an emulsion.

2.24 *Equipment.*—A powered rotary brush, with pressure feed line for introducing the detergent, should be used. The solution may be applied from a distance through a high-pressure water hose using a nozzle pickup tube. Commercial steam-cleaning equipment may also be used. A supply of clean rags should be on hand for wiping. Waterproof clothing, including goggles, rubber boots, and gloves should be provided for personnel.

2.25 *Personnel.*—For applying detergents by hand, the basic working crew should consist of a scrubber, two wipers, and a monitor.

2.26 *Technique.*—Large scale cleaning with detergents is best accomplished by application with steam. Following steam-detergent application, the surface should be flushed by hosing with water.

2.27 On a smaller scale, best results are obtained with a portable power-driven rotary brush with pressure feed. The solution for this machine should be mixed to such concentration that most of it remains on the surface as foam, thus lessening the danger of contamination due to runoff. Wiping should be done as soon as possible after scrubbing, first with a damp rag to remove most of the foam and waste, then with a dry rag.

2.28 In some cases it may be necessary to decontaminate by hand. On relatively small painted surfaces, good results have been obtained by rubbing the surface with a solution of hot water and detergent. Usually if one minute of such scrubbing does not remove most of the contamination, harsher methods are needed.

2.29 Rags used on vertical or overhead surfaces should not become so saturated with solution that they drip or cause runoff, occasioning further contamination. As soon as rags show any soil, they should be refolded so that a clean part can be used. Used rags should be placed in a special disposal unit. Re-use of these rags may cause further contamination.

2.30 The monitor should continually check the rags and the cleaned surfaces to determine how effective the process is and to locate areas that might require further scrubbing with detergents and scouring powder.

2.31 Detergents may also be used with acids or complexing agents to remove the greasy film that slows down chemical reaction.

2.32 *Limitations.*—Detergent solutions are not effective where the contamination has penetrated the surface. In addition, soap loses its emulsifying power in the presence of acid. Some of the new soapless detergents, however, emulsify effectively in either acidic or basic solutions. Detergents have the same limitations as other liquids, except that they are good agents for removing greasy dirt films, which readily pick up radioactive wastes.

Complexing Agents

2.33 In contact with contaminated materials, complexing agents (citrates, oxalates, and carbonates) form new molecular combinations which are more readily removed. Complexing agents are available in powdered form and can be mixed with water in the strength needed. Only small amounts are needed for decontamination. (About one pound of sodium citrate is sufficient to decontaminate 150 square feet of surface.)

2.34 *Equipment.*—Large scale decontamination will require power-driven apparatus such as a two-and-one-half ton truck carrying a 400-gallon tank fitted with high-pressure spraying nozzles. If complexing agents are used in a total immersion process, vats should be fitted with steam connections so that the solutions may be heated.

2.35 For smaller scale operations, pressure proportioners and nozzle pickup tubes designed for producing mechanical foam are needed. Figure 1 shows a pressure proportioner and nozzle pickup tube in series. This apparatus is used for mixing organic acids or complexing agents with mechanical foam. A supply hose delivers water to the pressure proportioner, which introduces foam-producing liquid into the water stream line. The mixture flows into the nozzle pickup tube, which draws the decontaminating solution into the stream and sprays the mixture on the surface to be decontaminated. This equipment will mix 3.6 gallons of decontaminating solution, 3.6 gallons of foam-producing liquid, and 56 gallons of water to produce 500 to 600 gallons of mechanical foam per minute.

2.36 Small hand pump water cans may be utilized in confined spaces. Chemical foam for fire fighting (aluminum sulfate and sodium carbonate) may be used.

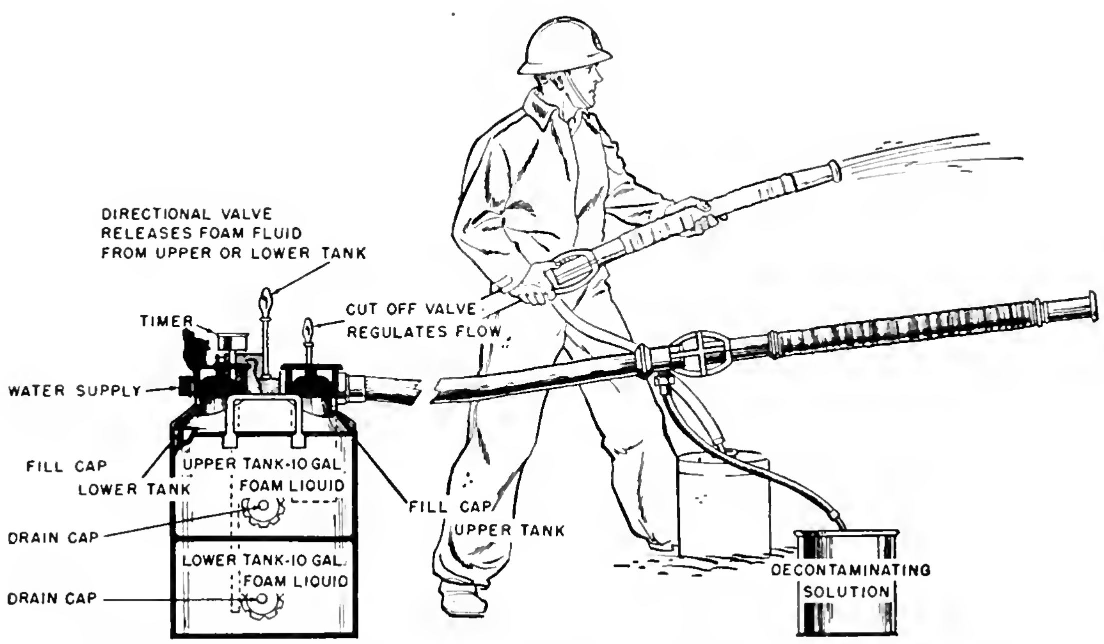


FIGURE 1.—Pressure proportioner and nozzle pickup tube in series.

2.37 Since complexing agents are generally noncorrosive and nontoxic, standard decontamination clothing will suffice.

2.38 *Technique.*—The surface to be decontaminated must be kept wet with the solution or foam, then completely flushed with water. The required time will depend largely on the length of time the surface has been contaminated. As a general rule, a 30-minute application of a 3 percent (by weight) solution of sodium citrate will effect an 80 to 90 percent reduction of radiation level. It may be necessary to respray at intervals to keep the surface moist during the reaction time.

2.39 A second application may be necessary. If, after the second application, the radiation level has not been reduced to the required point, an alternative method should be tried.

2.40 Mixing mechanical foam with complexing agents for use on vertical or overhead surfaces facilitates the spread of the agent. This is accomplished by running the water through a pressure proportioner to mix it with the foam-forming liquid, then passing the solution through a nozzle pickup tube. This draws in the complexing agent solution from a separate container, and sprays the mixture on the surface.

2.41 When using the mechanical foam apparatus, the concentration of the decontaminating solution should be about 3 percent. The concentration of the complexing agent should be 50 percent (by weight) since the solution is diluted in the apparatus before being sprayed on the surface.

2.42 *Limitations.*—Since complexing agents are rather mild reactors and have little penetrating power, they may not reach all of the contamination, especially if the surface is rusted or contains porous deposits. (Some complexing agents, however, such as oxalate, dissolve rust.) On vertical or overhead surfaces, unless the solution is mixed with adhesive, such as mechanical foam, it will tend to run off.

Organic Solvents

2.43 Such solvents as kerosene, gasoline, acetone, and carbon tetrachloride are used for quick removal of contaminated grease or paint. The speed of reaction makes organic solvents especially suitable for detailed cleaning by wiping procedures. Commercial paint removers are useful in paint stripping where immersion is possible.

2.44 *Equipment.*—Where immersion is used, a vat is needed for the solution and one or more for rinsing. Ventilation is necessary in enclosed spaces to prevent collection of harmful or flammable fumes.

2.45 *Personnel.*—A normal crew for vat or dip-bath operations and a monitor are needed.

2.46 *Technique.*—In vat dipping, crews should handle the material as little as possible. In immersion, small mobile cranes may be used to place the contaminated material in the dip-bath. After dipping, the material should be thoroughly rinsed with water and checked by the monitor. The paint or oil should be completely removed; if it is not, the material should be redipped. Metal still showing activity after removal of paint and grease should be routed to an acid bath.

2.47 Whenever concentration of radioactivity in the solvent bath is such that it causes recontamination of articles dipped, or when such radioactivity causes a health hazard around the bath, the solvent should be changed.

2.48 To facilitate rinsing, a wetting agent should be added to the solvent bath. This permits later flushing of decontaminated material with water, and removes the organic solvent which may remain on surfaces. Hand-wiping procedures may be used for paint stripping of small or otherwise inaccessible areas.

2.49 *Limitations.*—Organic solvents are toxic, flammable, expensive, and bulky.

Inorganic Acids

2.50 In this process, contamination in porous deposits on nonporous surfaces is removed when the acid eats away the porous material.

2.51 *Equipment.*—Large mixing tanks with rubber hose connections are recommended. Fiber hose is not suitable because of the acid's corrosive action on it. Wood or lead-lined vats are required for dipping operations. Personnel should be equipped with goggles, rubber gloves, and rubber boots in addition to other standard protective clothing. Rubber smocks may be needed if operators are subject to repeated splashing of acid. Canvas bootees or gloves are not advisable.

2.52 *Technique.*—Hydrochloric and sulphuric acids are the most suitable for large scale operations. Since acids will attack the metal surface as well as the deposits, they should be used in dilute form (9 to 18 percent hydrochloric or 3 to 6 percent sulphuric by volume) and with metal-corrosion inhibitors. The concentration should be maintained within the above limits. Dilution may result in reprecipitation of the contaminant. Periodic checks should be made of the solution, and when additional acid is needed, *the acid should be added to the water slowly while the solution is stirred.* Adding water to concentrated acid will produce a violent reaction.

2.53 After a surface has been treated with acid, it should be flushed with water, neutralized with a mild alkali, and then flushed with water again, to prevent further corrosion. Spots of remaining radioactivity may be removed by hand abrasion.

2.54 Acids are the best available chemicals for decontaminating pipe circulating systems. The solution should contain 13 percent by volume of concentrated hydrochloric acid. Circulating the solution through the pipes longer than four hours may cause excessive corrosion. Heating the solution, to a maximum of 125° F., may aid the action. The pipes should be flushed and neutralized following the operation, as outlined in the previous paragraph.

2.55 *Limitations.*—Diluted acids act more slowly than concentrated acids, and have little effect on paint. This process is not desirable where the utility of an object is impaired by removal of the surface layer.

Organic Acids and Mixtures

2.56 Some organic acids (such as acetic, citric, oxalic) or mixtures of mineral acids with sodium acetate, citrate, or oxalate, are more efficient than pure mineral acids.

2.57 *Equipment.*—Fire hose with a pressure proportioner or nozzle pickup, and an additional fire hose for flushing are sufficient. Crews should wear rubber boots, rubber gloves, goggles, and other water-resistant clothing.

2.58 *Technique.*—Contamination on an unweathered surface can be reduced approximately 90 percent in 1 hour by this method. Acid mixtures are used mainly for steel floor surfaces. The solution should be mixed in the proportion of one-tenth of a gallon of concentrated hydrochloric acid and two-tenths of a pound of sodium acetate to 1 gallon of water. The surface should be kept wet with the solution during reaction time. Flushing should follow the acid treatment.

2.59 On overhead and vertical surfaces the use of mechanical foam is recommended. The foam should contain citric acid and should be mixed with a pressure proportioner and a nozzle pickup tube. A 50 percent (by weight) solution of the acid is necessary to assure an adequate (approximately 3 percent) concentration of acid in the foam.

2.60 *Limitations.*—Acid mixtures are more corrosive than complexing agents but less corrosive than inorganic acids. Their use in decontamination will depend on the degree of corrosive action that is required or tolerated.

Decontamination With Caustics

2.61 Caustics may be used for removal of paint. They react on some metals such as aluminum, but do not act on steel or wood. About 1 pound of lye will remove 100 square feet of paint.

2.62 *Equipment.*—For extensive operations a large mixing tank with steam connections, a pump and a fire hose with an all-purpose nozzle are needed. For immersion processes, a large dipping tank with steam connections is necessary. Long-handled scrapers may prove useful.

2.63 Crews should wear rubber boots, rubber gloves, goggles, and other protective clothing.

2.64 *Technique.*—The solution is mixed in the proportion of 4½ pounds of lye to 6 pounds of any substance sold commercially as boiler compound to 7½ pounds of cornstarch with sufficient water to make 10 gallons of solution. The consistency of the solution will be such that it will adhere to vertical or overhead surfaces. The paint should be kept wet with the solution until most of it is soft enough to be washed off with a strong stream of water. This may require

983651°—52——3

from 15 minutes to 2 hours. Scraping may be necessary to complete the process.

2.65 Small vertical or overhead painted surfaces may best be decontaminated by trisodium phosphate solution. A hot 10 percent (by weight) solution rubbed on a surface for 1 minute will remove almost all contamination. Repeated application will destroy the paint.

2.66 *Limitations.*—Caustics are injurious to the eyes and skin; adequate protective clothing and goggles must be worn. Gloves and boots should be rinsed or wiped off before they are removed.

Abrasion Methods

2.67 Abrasion, the wearing away of the surface along with the contaminant, is the harshest but most effective surface decontamination method. The most efficient abrasion method in large-scale operations is vacuum blasting with controlled removal. Porous material such as brick and concrete can be treated by this method.

2.68 *Equipment.*—Sandblasting or vacuum blasting equipment for large surfaces and scrapers, grinders, or buffers for smaller operations are needed.

2.69 Figure 2 shows vacuum blasting equipment, consisting of a blast gun, abrasive separator, dust arrestor, and a vacuum jacket, with auxiliary sources of compressed air and electricity. In operation, steel or alloy abrasive is driven against the surface to be decontaminated by

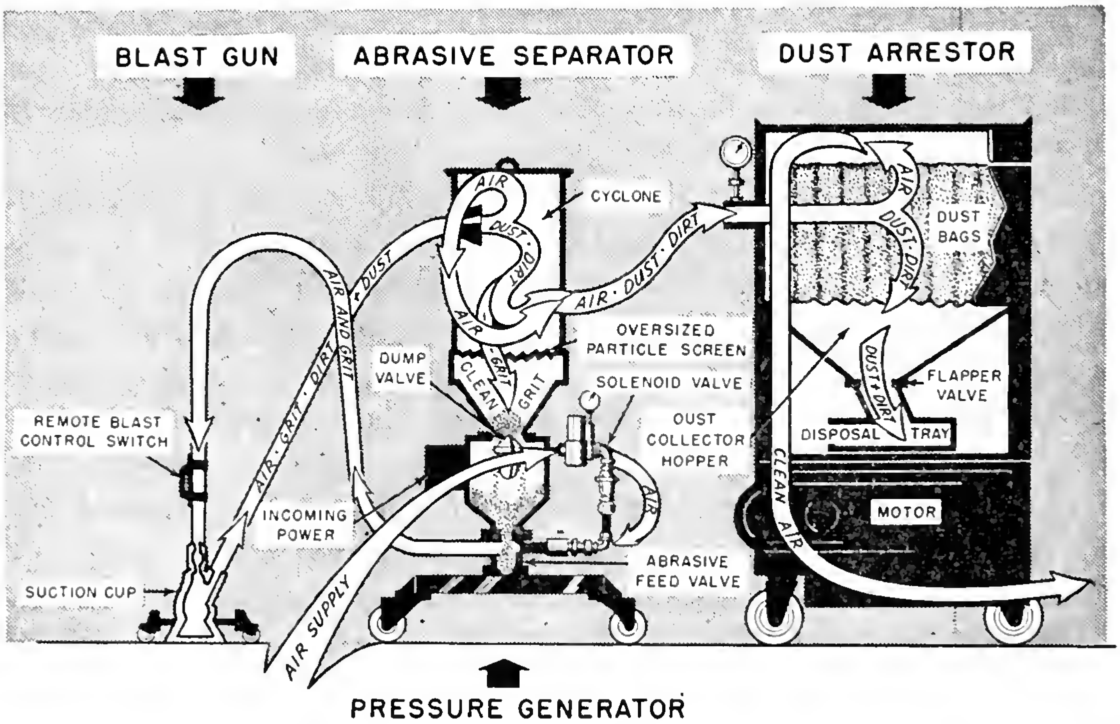
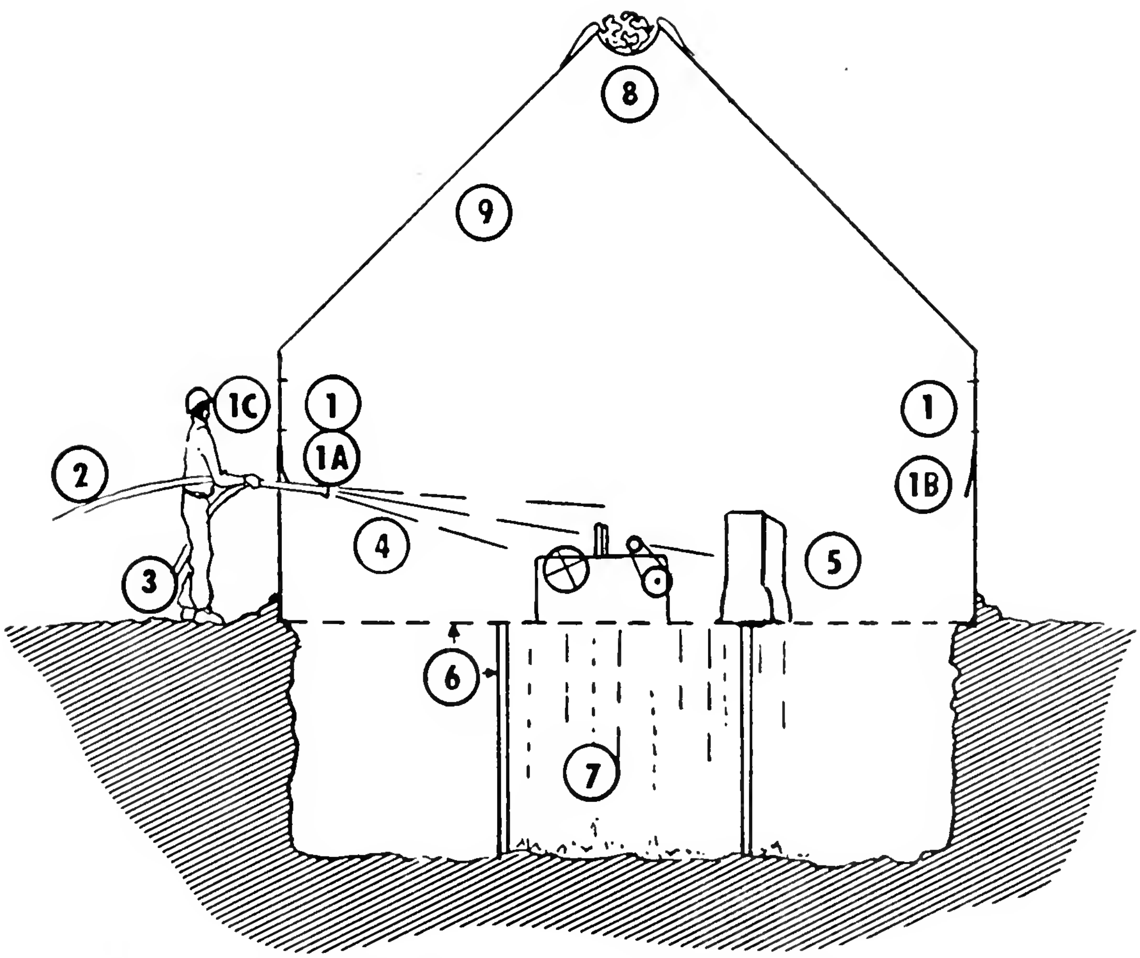


FIGURE 2.—Vacuum blasting equipment.

air pressure, and immediately picked up in the suction cup that fits around the blast gun. The abrasive and debris are pulled back through a hose into the chamber where the waste material and grit are separated. The grit drops into an air lock and is re-used, while the waste material passes to the dust bags. An operating rate of 100 square feet per hour is possible on horizontal painted surfaces.

2.70 For wet sandblasting an enclosed tent may be necessary, with nozzle openings and inside flaps on all sides, transparent plastic windows over every opening, and a loose filter (such as a bundle of cheese cloth) in the hole at the top. (See fig. 3.) The inside of the tent should be lacquered. With the tent, a perforated platform through which contaminated sand and water can drain, and a pit under the tent to collect the drainings, are needed. Hosing equipment is required.



1. Transparent plastic viewing port.
1A. Hole for blast gun with covering flap attached inside.
1B. Hole for blast gun.
1C. Position of operator.
2. Sand and air hose.
3. Water hose.
4. Blast gun.
5. Contaminated equipment on perforated cleaning platform.
6. Perforated runway strip or suitable substitute shored up to offer sufficient support.
7. Pit for contaminated waste and sand.
8. Filter cloth.
9. Canvas tent or equivalent.

FIGURE 3.—Tent for wet sandblasting.

2.71 In addition to standard protective clothing, workers need goggles and filter masks.

2.72 *Technique.*—Sample procedures on small areas will determine the best rate of decontamination.

2.73 Following sandblasting in the open, vacuum cleaning will help concentrate contaminated material spread in the process. Use of the tent is recommended for wet sandblasting. After blasting, the inside of the tent and the equipment and decontaminated object should be thoroughly hosed off. When the radiation level from the pit becomes high enough to interfere with monitoring or becomes a health hazard, the tent should be moved and the pit filled in and marked.

2.74 For small surfaces hand-operated buffers or grinders may be used. During operation the surface should be kept moist with detergents or complexing agents. Vacuum cleaning with equipment designed for moist surfaces will follow and the operation completed with a dry wipe of the surface.

2.75 *Limitations.*—For soft metals, hand methods or machine methods using soft grit or reduced air pressure for propelling the grit are necessary. On porous surfaces, where moisture must be used during operations, the abrasion method will be limited because the surface will absorb some of the contaminated moisture.

Flame Cleaning

2.76 In this method the radioactive substances on porous materials such as wood and concrete are trapped on the surface by burning before they can sink deeper into the material and are then removed. Flame cleaning is used when other methods might drive the contamination deeper into the material.

2.77 *Equipment.*—An oxyacetylene torch with a multiple-jet nozzle, a vacuum collecting hood with vacuum attachment, and wire brushes are needed. A fire extinguisher should be included. Protective clothing, dust masks, and goggles are required for the crews.

2.78 *Personnel.*—A flame cleaning crew should consist of three persons plus a monitor. One handles the flame nozzle, another scrapes the surface with a wire brush, and the third handles the vacuum equipment.

2.79 *Technique.*—The hood is placed over the area to be cleaned. The flame is pointed in the direction of the hood opening at an angle of approximately 45° to the surface. The amount of charring can be controlled by regulating the heat of the flame. On wood, the hotter the flame the better for rapid and shallow charring of the surface. On concrete, however, the flame temperature and time of application must be determined experimentally, so as not to glaze the surface and seal in the contamination. The average rate of cleaning is 5 square feet per minute on wood and 1⅔ square feet per minute on concrete. Following charring, the burned surface is removed by gentle abrasion with the brushes and the contaminated material collected with vacuum equipment.

2.80 *Limitations.*—The rate of cleaning is slow. A fire hazard is created under certain circumstances. In addition, considerable amounts of radioactive material may escape into the air despite the hood.

AGING AND SEALING

3.1 Aging as a method of decontamination refers simply to allowing time for radioactive decay to reduce the hazard. Sealing prevents dispersion of the contaminating material by fixing the substance to the surface. It also affords ample shielding for the alpha and the low energy beta radiations. Sealing may be done immediately, if the beta-gamma intensities do not themselves constitute a hazard. Preliminary gross decontamination, such as hosing, may be necessary before sealing is done; or, if time permits, aging followed by sealing may be the decontamination method of choice.

Necessary Characteristics

3.2 Most common sealing materials are asphalt, paint, and grout. A good sealing material should have the following characteristics:

(*a*) Good adhering qualities and the ability to resist cracking or flaking.

(*b*) Chemically inert to prevent reactions with substances likely to come in contact with it.

(*c*) Nonporous and waterproof to prevent diffusion of the contamination through the sealer to the surface.

(*d*) Ability to dry or set within a few hours.

(*e*) Wear-resistant to minimize possibility of seal breakage.

(*f*) Heat-resistant within the range of temperature expected on the surface to be decontaminated.

(*g*) Adaptable to fast application techniques, such as spraying.

3.3 The type of sealing material used will depend on the surface to be decontaminated. For instance, long-wearing characteristics might be a prime consideration in choosing a sealing material for a roadway while ease of application might be the deciding factor in choosing a sealer for large vertical surfaces.

3.4 Sealed surfaces should be so marked and with the date of sealing.

Asphalt and Asphalt Concrete

3.5 Standard resurfacing materials such as asphalt and asphalt concrete are the most common sealing materials for roadways and large land areas. These materials can withstand hard, continuous wear.

3.6 *Equipment.*—Commonly used road resurfacing equipment will do the job. Personnel should be provided with filter masks and goggles in addition to standard decontamination clothing.

3.7 *Technique.*—A relatively permanent seal may be obtained through normal resurfacing operations. "Road mix" techniques should be avoided as they tend to stir up contamination. A rapid method of applying the seal is by spraying with hot asphalt. However, such a seal will last a few months at the most.

Paints and Plastics

3.8 A quick method of sealing large vertical or overhead surfaces is by spraying with paint or plastic.

3.9 *Equipment.*—Conventional spraying equipment may be used. Portable or mobile air compressors are desirable. Personnel should wear filter masks as well as the usual decontamination outfits.

3.10 *Technique.*—Prior to spraying, the surface or object may be partially decontaminated by hosing. The paint or plastic should be applied in one heavy coat, with runs held to a minimum. Spray guns and lines should be carefully cleaned before and after use to prevent contamination of sealing material. Warning signs should be placed until the paint or plastic is dry.

3.11 These coatings, however, do not provide a permanent seal; periodic inspection is necessary, at intervals of from 1 to 6 months, depending on the conditions to which the surface is subjected.

Sealing With Grout

3.12 Sealing may be accomplished by spraying with grout—a thin mixture of sand, cement, and water. Such a seal is only semipermanent, and grout is somewhat porous.

3.13 *Equipment.*—Necessary equipment includes a cement mixer, large air compressor, and heavy-duty fire hose with hopper connections for introducing cement under air pressure. Figure 4 shows mobile equipment for spraying grout. It consists of a cement mixer

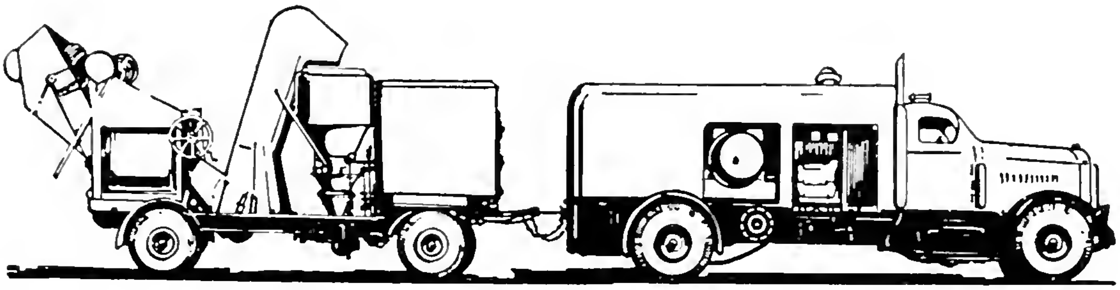


FIGURE 4.—Mobile equipment for spraying grout.

and hopper mounted on a trailer, and a prime mover containing an air compressor. Cement and sand are carried, in the dry state, through the hopper to the nozzle where they are mixed with water and sprayed upon the surface to be sealed. This equipment can apply the grout mixture at the rate of about 18 cubic feet per hour. Personnel should be equipped with goggles and filter masks in addition to standard decontamination outfits.

3.14 *Personnel.*—Crew should consist of at least six men. Two operate the cement mixer, two feed the mix into the hopper, and two apply the spray.

3.15 *Technique.*—Ground on which the materials are to be dumped should be decontaminated to prevent radioactive materials from being mixed into the grout. Wire mesh should be placed on the surface to be sealed as a framework for the grout. If the surface to be sealed is rough, no framework is necessary, as the grout will adhere without further preparation. The operator should be 2 to 4 feet from the surface and direct the spray to strike at right angles. At least one-quarter inch of grout should be applied. During the spraying process special attention should be directed to corners, cracks, and joints to insure complete sealing in of the contamination. Grout which rebounds from the surface should not be re-used.

3.16 Hand plastering methods are too slow and hazardous to be practical.

REMOVAL AND STORAGE

4.1 Following an A-bomb attack entire city blocks might be blasted into rubble. Industrial areas and large business districts might be contaminated beyond the point of salvage. Decontamination for such large areas would call for the removal of contaminated objects. Most such objects would have to be reduced in size to facilitate handling and the radioactive contamination on their surfaces concentrated to prepare the materials for removal and storage.

Demolition and Concentration

4.2 To reduce the volume of material that should be stored, it is often necessary to demolish objects, separate contaminated from uncontaminated materials, and burn contaminated combustibles under carefully controlled conditions to prevent spread of contamination.

4.3 Demolition should be carried out with a minimum of handling by personnel. Material should be continuously monitored, as some of the material may not be contaminated and thus may be subject to salvage. Material which appears to be uncontaminated should be set aside on special platforms where it can be rechecked. If uncontaminated it can be stockpiled for re-use or otherwise removed without special attention. The concentrated radioactive material which remains following demolition processes should be stored where it will remain away from human contact.

Combustible Material

4.4 Combustibles will comprise a large part of the material exposed to possible contamination. Concentration of contamination for removal through the process of controlled burning near the original site is desirable. Although burning reduces the bulk of combustibles to about 1 percent of the original, as much as 50 percent of the radioactive substances can become airborne in the fly ash. Therefore, recovery of the fly ash is an essential objective of any controlled burning operation.

4.5 *Equipment.*—An incinerator, varying from a mobile unit to a semipermanent installation, is required. The firebox should be of such design that all combustible material is oxidized and all moisture vaporized to achieve maximum reduction of material. In large installations a traveling burning surface or grate may be desirable.

4.6 For recovering fly ash one of the following types of equipment may be used:

(*a*) Fixed filter.
(*b*) Wet scrubber.
(*c*) Dry precipitator.
(*d*) Disposable filter.

These are described later in this chapter.

4.7 Filter masks and goggles, in addition to standard decontamination clothing, should be worn by personnel.

4.8 *Technique.*—Most efficient burning can be obtained by charging the incinerator with small fragments or by aiding the burning process with coke or some similar fuel. Induced draft should be provided to insure complete burning and prevent back pressure by the fly ash removal process. Draft by means of a fan in the exhaust passage should be avoided.

4.9 Ashes remaining after burning should be sieved, and partially burned material should be passed through the incinerator again. Metal pieces should be monitored and reclaimed, or removed with other radioactive waste. During the handling the ash should be moistened to reduce airborne hazard.

4.10 *Recovering fly ash.*—Fixed filters, one means of recovering fly ash, are usually built into the incinerators. They are made of noncombustible material such as glass, metallic, or asbestos fibers.

4.11 For gases containing little tar in suspension, the wet cleaning method of recovering fly ash may be desirable. The escaping gas may be passed through water or water spray to trap the fly ash.

4.12 If the suspended matter contains tar, dry precipitation is a better, though more elaborate, method of cleaning. This method requires the use of such devices as centrifugal cleaners and coke or sawdust scrubbers. For most effective cleaning an electrostatic precipitator may be needed.

4.13 If equipment for these methods is not available, disposable filters should be constructed or improvised. One improvisation would be to direct the flue gases through water. Another way would be to direct the gases through a ditch packed with rock, soil, sawdust, and charcoal. Coke and charred wood are valuable filtering agents.

4.14 Contaminated ash and other radioactive materials that remain following the incineration process should be placed in containers and stored as noncombustible material.

Inert and Fusible Material

4.15 Bulky inert and fusible materials may be broken down into more easily handled pieces. In addition it may be desirable to reclaim some of the major metals, such as iron, copper, tin, lead, aluminum, and their alloys.

4.16 *Equipment.*—Demolition can be accomplished with cutting torches and standard conventional wrecking equipment.

4.17 In addition to standard protective clothing, personnel should wear filter masks and goggles.

4.18 *Technique.*—The contaminated material is reduced, with the equipment necessary to do the job, to easily handled pieces. Uncontaminated pieces resulting should be separated from contaminated, to facilitate removal of the latter.

4.19 Debris should be kept moist to reduce any contaminated dust hazard. When cutting operations used in demolition of metallic structures are done in enclosed areas, the danger from airborne contaminants can be reduced by circulating fresh air into the areas.

4.20 If reclamation of the metal is desirable, the surface should be cleaned by the dip-bath method described in chapter 2. If the condition of the surface is not an important consideration, stronger solutions may be used, such as five-normal hydrochloric acid (40 percent by volume).

Precautions in Handling

4.21 Decontamination procedures result in large quantities of radioactive waste that must be moved to temporary and permanent storage sites. Handling of such waste should be done in a manner that provides maximum personnel protection and prevents contamination of uncontaminated areas.

4.22 Moistening of radioactive wastes, especially during loading and unloading operations, will reduce dust hazards. Whenever possible, the waste should be handled by remote control. Use of such equipment as cranes, power shovels, and fork lifts is recommended.

4.23 The fork-lift can be adapted for various lifting and handling operations required in decontamination. Figure 5 shows a light boom

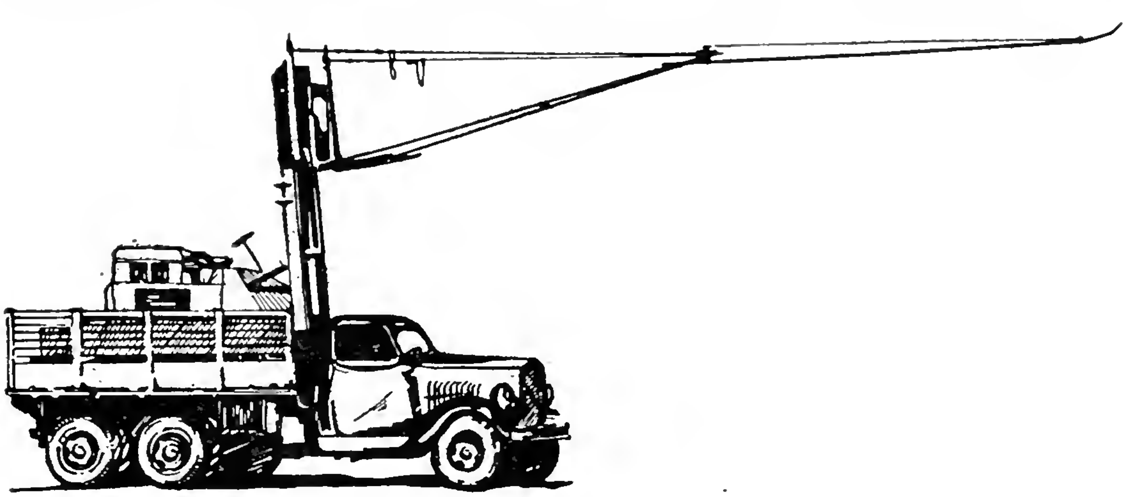


FIGURE 5.—Fork-lift.

crane mounted on the fork-lift and the fork-lift mounted on a 2½-ton truck for mobility. The crane can be used for moving decontaminating apparatus or monitoring devices close to radioactive areas with minimum exposure to the operator.

4.24 When moving wastes for any distance, covering the material with tarpaulins is advisable. Packaging may be necessary in some cases. Standard 55-gallon metal drums may be used for this purpose. Such containers provide some radiation shielding and facilitate remote control handling of the material.

STORAGE METHODS

5.1 Storage of radioactive wastes may be either temporary or permanent. The type of storage used will depend on the location, time, personnel, and material available. Temporary storage is the easier and quicker method, but it can prevent escape of radioactive material for only a limited time. Considerable preparation is necessary for permanent storage, but it can prevent dispersion indefinitely. Eventually all wastes will have to be stored permanently or dispersed under careful controls.

5.2 Whether temporarily or permanently stored, the material should be placed where it can be safely approached. In the case of temporary storage, this permits recovery of the material for permanent storage. For permanently stored material it allows for inspection to locate possible leakage or dispersion of waste material. In addition, the material may be recovered when it is no longer dangerous.

5.3 There are three general types of storage—burial on land, entombment, and burial at sea.

Burial on Land

5.4 Land burial will be used for areas which are far from the sea and have no entombment sites in the vicinity. It may be either permanent or temporary. If temporary, consideration must be given to recovering the stored material at a later date for permanent storage.

5.5 *Equipment.*—Large scale operations require such equipment as earth-moving and digging equipment, core-drilling machinery, and concrete mixers.

5.6 *Location.*—The burial site should be as close to the area of contamination as possible, to cut down the distance the material must be transported.

5.7 Ground water conditions should be considered in locating permanent burial cells. Permanent cells should be located on bedrock to prevent damage from settling and shifting. If this cannot be done, footings of piling or concrete piers should be constructed. Natural ground depressions such as small valleys or ravines may be used as an alternative to excavation.

5.8 For temporary storage, natural depressions are usually more desirable than excavations, as they save time that would otherwise be needed for digging. Sites with a heavy runoff of rain water should be avoided, since erosion would cause further spread of contamination.

5.9 When locating a burial site, the possibility that radioactive material may seep out of an unlined burial cell must be taken into consideration. Since seepage of radioactive liquid wastes is less likely through clay than other types of earth, locating burial chambers in clay substrata is desirable. Sand or rock substrata are least effective in stopping seepage.

5.10 Location of the water table is another important consideration in locating burial chambers. Radioactive seepage can contaminate the water supply of the surrounding area. Accordingly, a low water table is desirable. Information regarding drainage, substrata, and water tables can be obtained from the State engineer, the State geologist, or the engineering staffs of the local governments.

5.11 *Technique.*—For permanent burial an excavation is made and lined with concrete. The interior should be waterproofed with grout or similar material and acidproofed if necessary. The cell thus made may be filled with the wastes to within 6 feet of the surface. Four or five feet of earth should be placed over the wastes before the concrete roof is poured. This allows for later removal of the concrete cover and recovery of the wastes, if necessary, without contacting the active material. Sufficient earth should be placed over the cell to prevent accidental uncovering and to reduce ground level radiation to a minimum. Core drills or wells should be placed alongside the cell and inspected periodically to detect any leakage or deterioration of the cell walls.

5.12 The land over a permanent storage cell may be used for normal agricultural and industrial operations; however, heavy structures should not be placed over the cell.

5.13 In temporary storage, no lining is necessary for the excavation or natural depression. The wastes may be covered with concrete, as in the case of permanent cells, or with dirt and surfaced with asphalt. *The land over a temporary cell should not be used for any purpose and should be adequately marked with warning signs.*

Entombment

5.14 Entombment is simplified burial in such places as abandoned or low-grade mines or natural caves.

5.15 *Equipment.*—Equipment for handling materials in mines is needed. Concrete mixers may be necessary.

5.16 *Location.*—The site should be dry to prevent drainage of radioactive substances into water courses.

5.17 *Technique.*—If the materials to be stored are in leakproof containers no special sealing of the chamber is required. If the wastes are unpackaged the chamber should be sealed with concrete or similar material to prevent leakage. If damp conditions are unavoidable, the containers should be treated to prevent corrosion. The entrance of the cavern or room containing the stored material should be blocked off with concrete and earth to prevent accidental approach to the material. Location of the site should be recorded and the entrance inspected periodically.

Burial at Sea

5.18 In general, the primary advantages of burial at sea are that it is cheaper and valuable land need not be sacrificed. Since dispersion of large amounts of radioactive substances in the sea is not desirable, containers that will hold the wastes captive for long periods of time should be used. Deterioration of the containers would be slow enough to prevent dangerous reconcentration of the radioactive substances. Liquids as well as solids can be disposed of by this method.

5.19 *Equipment.*—Materials and equipment for constructing steel boxes, lining them with concrete, and painting and coating them; devices for lifting the boxes; cement mixers; and vessels for transportation are needed.

5.20 *Location.*—Perhaps the best location is in the very deep submarine canyons in areas where the ocean bottom is shifting so that the containers will be covered by natural processes. Since this might not be practical, disposal beyond the continental shelf—in water not less than 100 fathoms and in places where strong currents are absent—is satisfactory. Sea burial operations must be conducted with the cognizance of the United States Coast Guard and the Naval Districts concerned.

5.21 *Technique.*—Large rectangular or cylindrical steel boxes should be made. A 4-inch lining of concrete is recommended. Total weight, including the waste material, should not exceed 50 tons. The boxes should be fitted with lifting pads for handling. The exterior of the steel containers should be painted with red lead and coated with a leakproof compound to protect them from corrosion.

5.22 If emergency conditions prevent the construction of special boxes, available containers which are fairly large, reasonably strong, and leakproof should be used. They should be capped and sealed, and completely filled to prevent rupture by high pressures at great depths.

CONCLUSION

6.1 Decontamination by civil defense crews will be an emergency measure and will consist primarily of gross decontamination. The objective of such measures will be to make contaminated areas and equipment radiologically safe for immediate use following an enemy attack. For instance, decontamination procedures may be required before engineering crews responsible for restoring utilities can start operations. Thus, decontamination personnel must be so organized, equipped, and trained that they can go into action soon after an attack.

6.2 Any one decontamination method or combination of methods described in this manual may be required, as the situation demands. Civil defense decontamination operations ordinarily will not go beyond the primary objective of making an area or equipment safe for postattack civil defense operations.

SURFACE DECONTAMINATION METHODS

A. Classified by Agent

Agent	*Type of surface*	*Situations*
Vacuum cleaning	Dry	Where contamination is in form of dust. Interiors of buildings.
Water	Nonporous (metal, paint, plastic, etc.).	Decontamination from a distance. Fixed or movable items.
Steam	Painted or oiled, nonporous.	Rooms where contaminated spray can be controlled. Buildings.
Detergents	Nonporous (metal, paint, plastic, etc.). Industrial films, oils and greases.	Surface covered with atmospheric dust and grease. Fixed or movable items.
Complexing agents	Metal or painted	Large, unweathered surfaces. Surfaces where corrosion is not tolerable. As an adjunct to water or steam treatment.
Organic solvents	Painted or greased	Final cleaning. Where complete immersion dipping operations are possible. Movable items.
Inorganic acid	Metal or painted especially those exhibiting porous deposits, such as rust, marine growth.	Decontamination of pipe circulating systems. Dipping of movable items.
Organic acid mixtures.	Metal and painted	Large surfaces. Both fixed and movable items.
Caustics	Painted	Large surfaces. Dipping of painted objects.
Abrasion	Metal and painted	Large, weathered surfaces. Fixed or movable items.
Flame cleaning	Unpainted concrete and wood. Corroded metal.	Floors, roads, structures requiring repainting.

B. Classified by type of surface

Surface	*Method*	*Advantages*	*Disadvantages*
Paint	Water	Most practical method for gross decontamination from a distance. Contamination reduced by approximately 50 percent.	Protection needed from contaminated spray. Runoff must be controlled. Water under high pressure should not be used on a surface covered with contaminated dust.
	Steam (with detergent if available).	Most practical method for decontaminating large horizontal, vertical, and overhead surfaces. Contamination reduced by approximately 90 percent.	Same as for water.
	Soapless detergents	Where effective, reduces activity to safe level in 1 or 2 applications.	Mild action.
	Complexing agents: Oxalates, carbonates, citrates.	Holds contamination in solution. Contamination on unweathered surfaces reduced by approximately 75 percent in 4 minutes. Easily stored, nontoxic, noncorrosive.	Requires application from 5 to 30 minutes for effectiveness. Has little penetrating power; hence of small value on weathered surfaces.
	Organic solvents	Quick dissolving action makes solvents useful on vertical and overhead surfaces.	Toxic and flammable. Requires good ventilation and fire precautions.
	Caustics	Minimum contact with contaminated surface. Contamination reduced almost 100 percent.	Applicable only on horizontal surfaces. Personnel hazard. Not to be used on aluminum or magnesium.
	Abrasion (wet sandblasting)	Complete removal of surface and contamination. Feasible for large-scale operations.	Contaminated sand spread over large area. Method too harsh for many surfaces.

Metal	Water	Contamination reduced by approximately 50 percent.	Same as for painted surfaces.
	Detergents	Removal of oil or grease films	Do.
	Organic solvents	Stripping of grease	Do.
	Complexing agents: Oxalates, carbonates, citrates.	Holds contamination in solution	Difficult to keep in place on any but horizontal surfaces. Limited value on weathered or porous surfaces.
	Inorganic acids	Fast, complete decontamination	Good ventilation required; acid fumes toxic to personnel. Possibility of excessive corrosion. Acid mixture cannot be safely heated.
	Acid mixtures	Action of weak acid. Reduces contamination of unweathered surfaces.	Same as for inorganic acids.
	Abrasion (buffers, grinders)	Useful for detailed cleaning	Follow-up procedure required to pick up powdered contamination.
	Abrasion (wet sandblasting)	Same as for painted surfaces	Same as for painted surfaces.
Concrete	Abrasion (vacuum blasting)	Direct removal of contaminated dust	Contamination of equipment.
	Vacuum cleaning	Same as for vacuum blasting on concrete	Same as for vacuum blasting on concrete.
	Flame cleaning	Only method of trapping contamination on surface.	Slow and painstaking. Fire and airborne radiation hazard is great.
Brick	Same as for concrete	Same as for concrete	Same as for concrete.
Asphalt	Abrasion	No direct contact with surface; contamination may be reduced to safe level.	Residual contamination fixed into asphalt If road is subject to further contamination, may require recovering.
Wood	Flame cleaning	Same as for flame cleaning on concrete	Same as for flame cleaning on concrete.

The following Federal Civil Defense Administration publications are on sale by the Superintendent of Documents, Washington 25, D. C.

1. United States Civil Defense, 1950, 25 cents, 168 pp. The national plan for organizing the civil defense of the United States.

Administrative Guides

1. Civil Defense in Industry and Institutions, Pub. AG-16-1, 1951, 25 cents, 64 pp. Plans for organizing and administering civil defense self-protection programs for the Nation's industrial plants, office and apartment buildings, and other institutions.
2. The Clergy in Civil Defense, Pub. AG-25-1, 1951, 10 cents, 12 pp. Guide for the clergy of all faiths for determining their place and function in civil defense.
3. Emergency Welfare Services, Pub. AG-12-1, 1952, 20 cents, 62 pp. Guide for developing a program to meet the multiple welfare problems that would arise from enemy attack.
4. Engineering Services, Pub. AG-13-1, 1952, 15 cents, 26 pp. Assists State and local civil defense directors in planning and establishing their engineering services.
5. Fire Services, Pub. AG-9-1, 1951, 15 cents, 27 pp. Basic guide to assist States and communities in planning, organizing, staffing, and operating an expanded fire-fighting service during periods of war emergency.
6. Health Services and Special Weapons Defense, Pub. AG-11-1, 1950, 60 cents, 264 pp. Methods for organization of all basic health and special weapons defense (atomic, biological, and chemical warfare) for State and local civil defense programs.
7. Police Services, Pub. AG-10-1, 1951, 20 cents, 48 pp. Basic guide for State and local civil defense officials in organizing and directing police civil defense services.
8. Principles of Civil Defense Operations, Pub. AG-8-1, 1951, 20 cents, 48 pp. Basic guide in planning and organizing for mutual aid and mobile support operations.
9. The Rescue Service, Pub. AG-14-1, 1951, 15 cents, 32 pp. Basic guide for State and local civil defense officials in organizing rescue services and training rescue teams.
10. The Warden Service, Pub. AG-7-1, 1951, 20 cents, 48 pp. Basic guide for civil defense directors and supervisory wardens in selecting, organizing, training, and equipping the warden service.

Public Booklets

1. Duck and Cover, Pub. PA-6, 1951, 5 cents, 14 pp. Cartoon instruction for children on what to do in case of atomic attack.
2. Emergency Action to Save Lives, Pub. PA-5, 1951, 5 cents, 32 pp. Practical instructions for the untrained person on the emergency care of injured people.
3. Fire Fighting for Householders, Pub. PA-4, 1951, 5 cents, 32 pp. Information for householders on how fires start, how they can be prevented, and how to fight a fire.
4. Survival Under Atomic Attack, 1950, 10 cents, 32 pp. Techniques of personal survival under atomic bomb attacks.
5. This Is Civil Defense, Pub. PA-3, 1951, 10 cents, 32 pp. Highlights of the national civil defense program and how the volunteer can make civil defense a success.
6. What You Should Know About Biological Warfare, Pub. PA-2, 1951, 10 cents, 32 pp. Techniques of personal survival under biological warfare attacks.

Technical Manuals and Handbooks

1. Outdoor Warning Device Systems, Pub. TM-4-1, 1951, 15 cents, 36 pp. Data for planning, procuring, and installing public warning device systems for civil defense.
2. Shelter from Atomic Attack in Existing Buildings, Part I – Method for Determining Shelter Needs and Shelter Areas, Pub. TM-5-1, 1952, 20 cents, 53 pp. Instructions, forms, and recommendations for use of civil defense directors, survey teams and their supervisors, and technically qualified personnel in conducting a shelter survey.
3. Water Supplies for Wartime Fire Fighting, Pub. TM-9-1, 1951, 10 cents, 16 pp. Program for increasing available water supplies to meet the needs of emergency water-supply operations during wartime.
4. The Warden's Handbook, Pub. H-7-1, 1951, 15 cents, 34 pp. Basic reference aid for the block warden.